WoF / Hi-Impact Wx Workshop
1 April 2014 – Norman, OK
10 Apr 2014 - Modified for DTC meeting

From RAPv3/HRRR-2014 to the NARRE/HRRRE era

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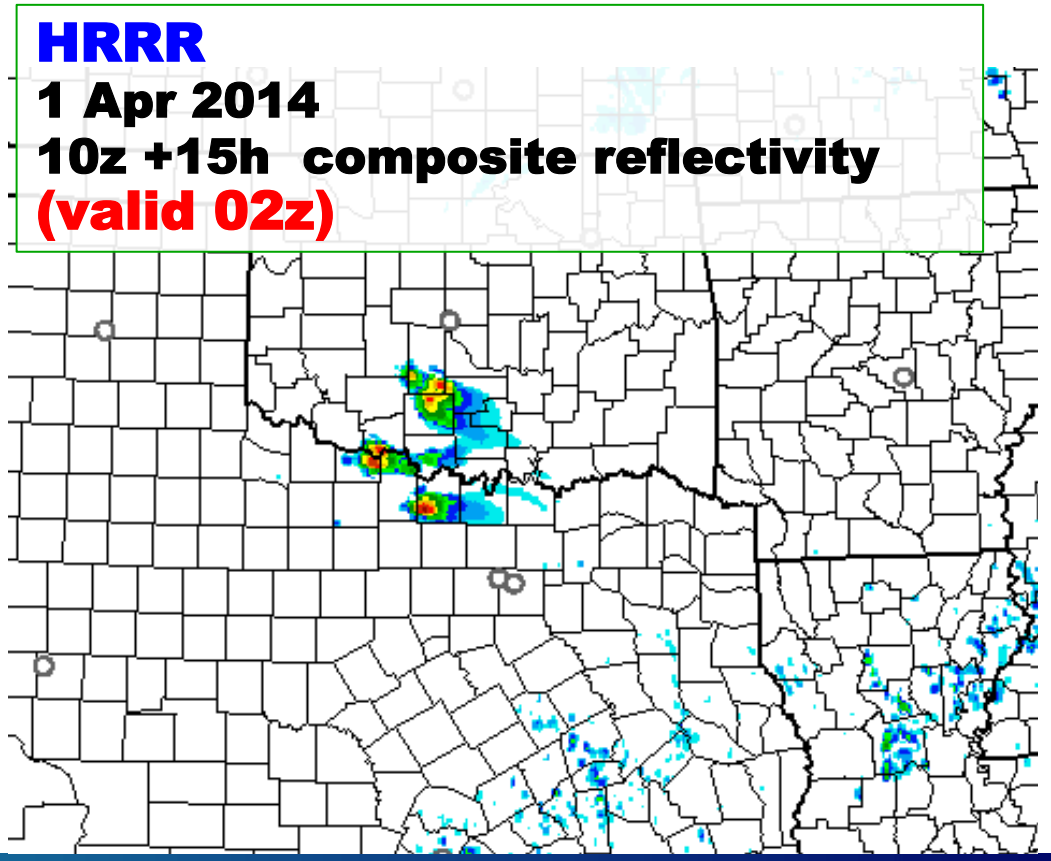


Earth System Research Laboratory
SCIENCE, SERVICE & STEWARDSHIP

NCEP implementations of RAP version 2 and HRRR

RAP

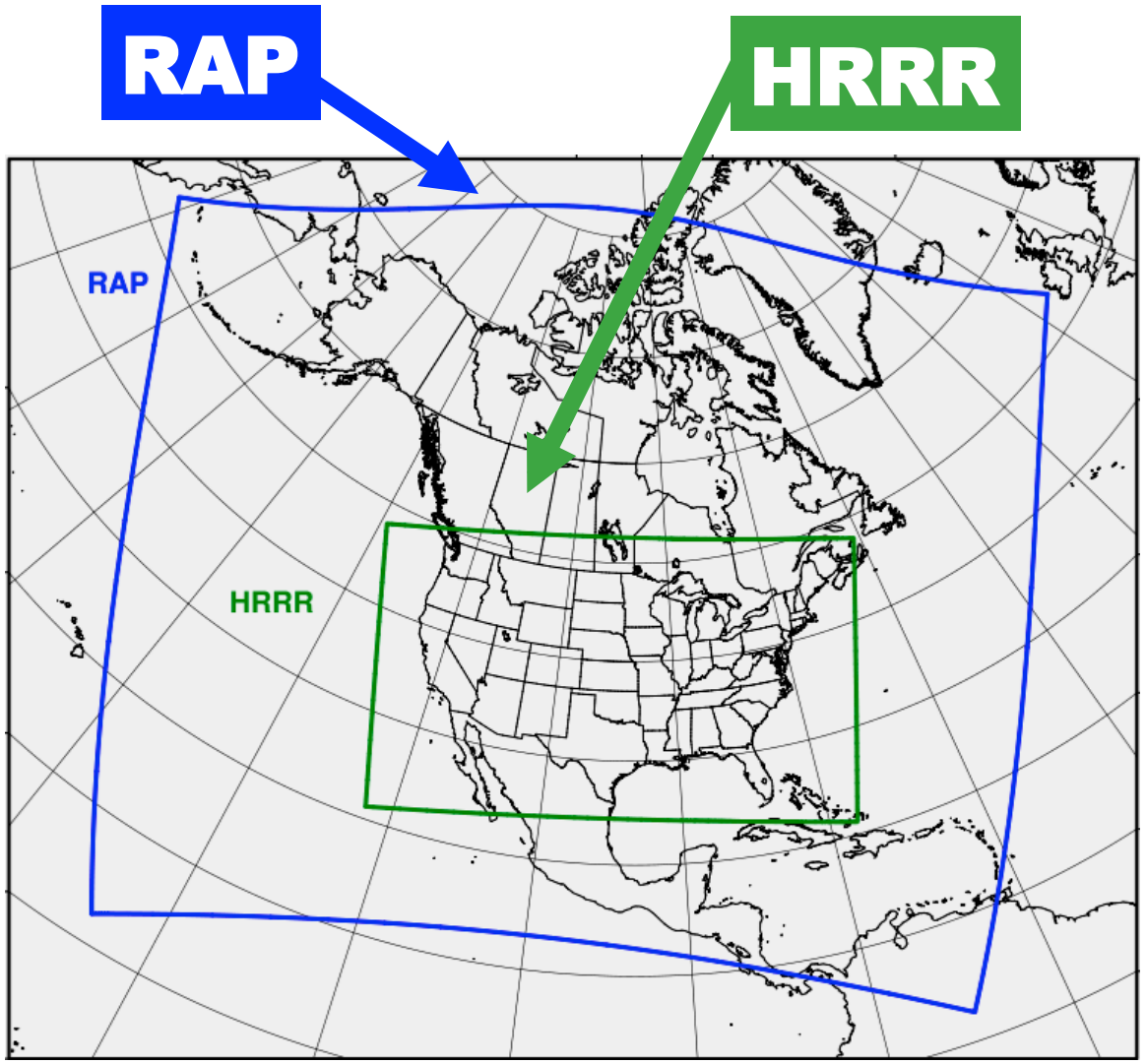
"Version 2" real-time at GSD, final testing NCEP

"Version 2" **NCEP implementation occurred 25 Feb 2014**

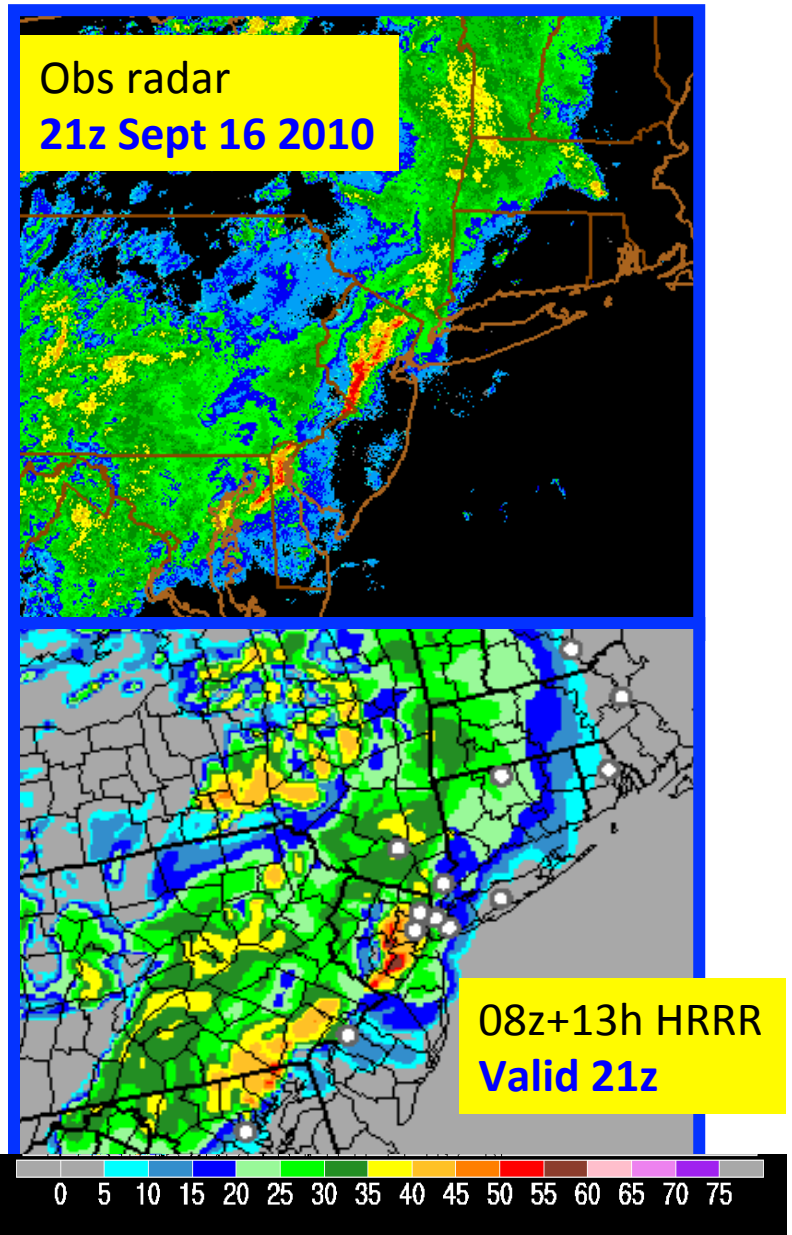
HRRR

Real-time experimental at GSD, testing at NCEP

Planned NCEP implementation August 2014

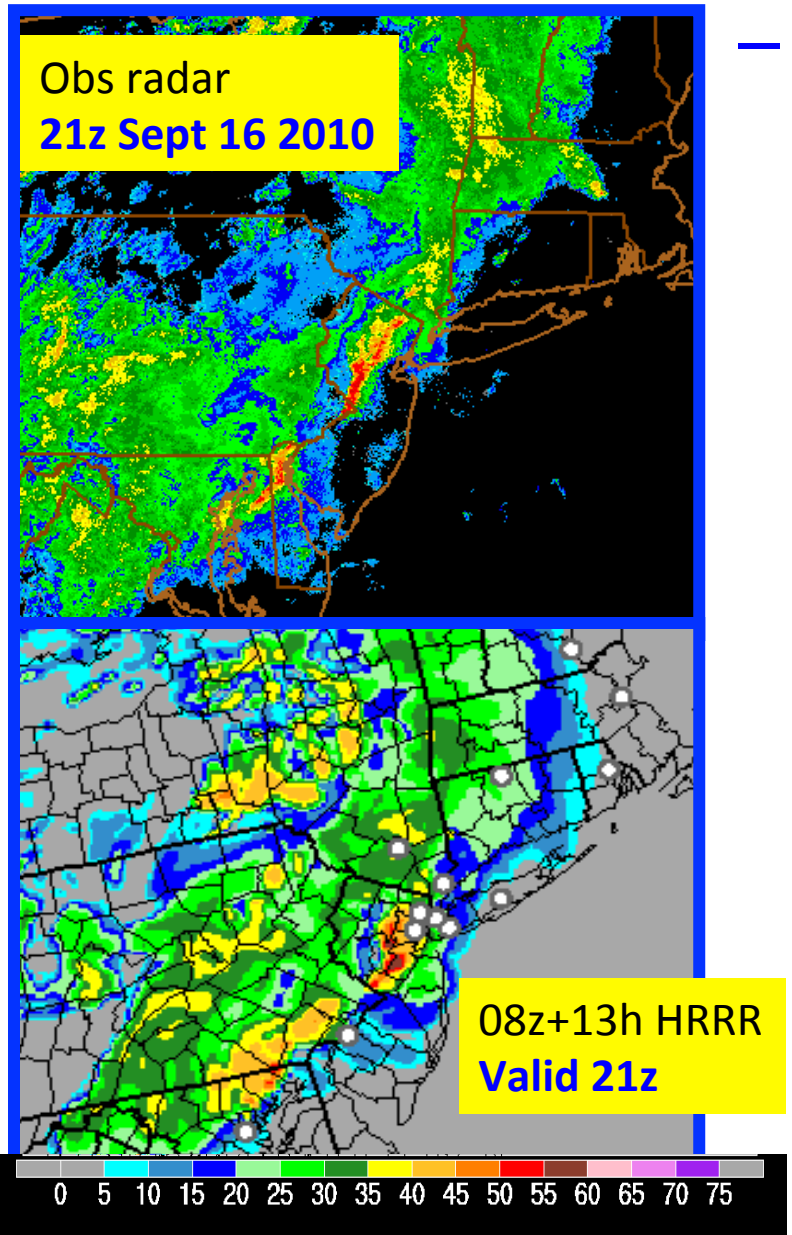


Purpose - Weather Model Development for RAP/HRRR



- ***Development*** of the Rapid Refresh (RAP) and HRRR models (NAM, NARRE/HRRRE also)
- Hourly data ***assimilation*** of latest observations to initialize the RAP and HRRR
- ***Application*** of HRRR and RAP to aviation/severe weather/ energy applications
  - HRRR/RAP are backbone for most 1-18h aviation weather products
- ***Implementation*** of RAP and HRRR to NOAA operational models at NCEP

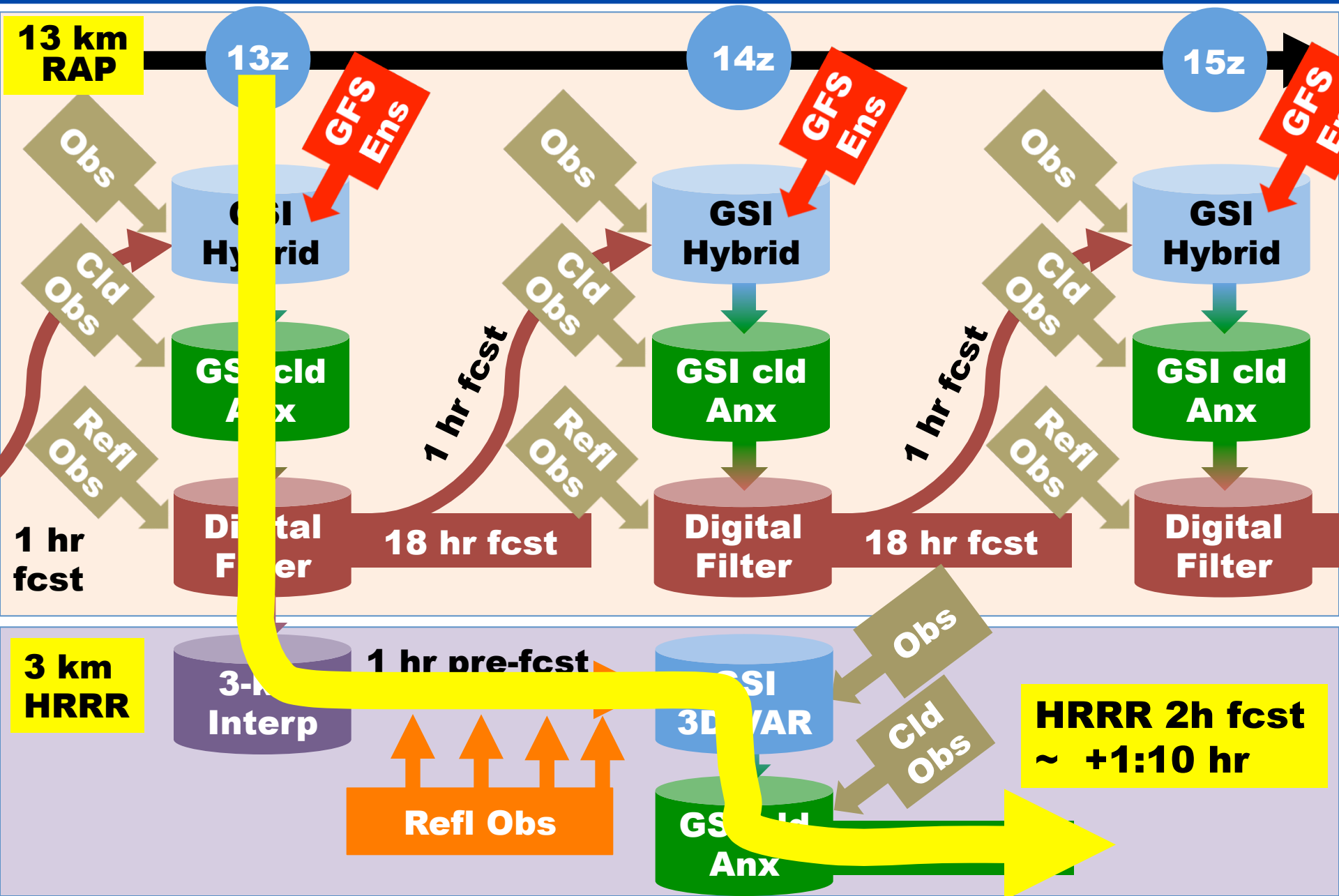
Weather Model Development for RAP/HRRR



– **Inter-lab/center interactions**

- **Development partners** –
  - NCAR,
  - MIT/LL
  - U. Oklahoma
  - NCEP (National Centers for Environmental Prediction – within NWS/NOAA)
- **Operational evaluation**
  - NWS Regions (Eastern, Central, Southern, Western, Alaska)
  - NWS Forecast Offices (~125 of them)
  - Aviation Weather Center, Kansas City, MO
  - Storm Prediction Center, Norman, OK
  - FAA, DOE, private sector
- **Implementation** – NCEP (EMC, NCO) at NOAA/National Weather Service

2013 HRRR Initialization from RAP



WRF-ARW / GSI enhancements for RAP

- **GSD contributions to WRF-ARW**
  - Grell 3-D cumulus scheme
  - RUC (Smirnova) Land Surface Model
  - Enhancement to MYNN (Mellor-Yamada Nakanishi/Niino) boundary layer scheme
  - Diabatic Digital Filter Initialization (with NCAR)
  - DFI-radar reflectivity assimilation
- **GSD contributions to GSI**
  - Non-variational cloud analysis
  - Ingest for cloud / hydrometeor fields, radar / obs
  - Enhancements to surface obs assimilation

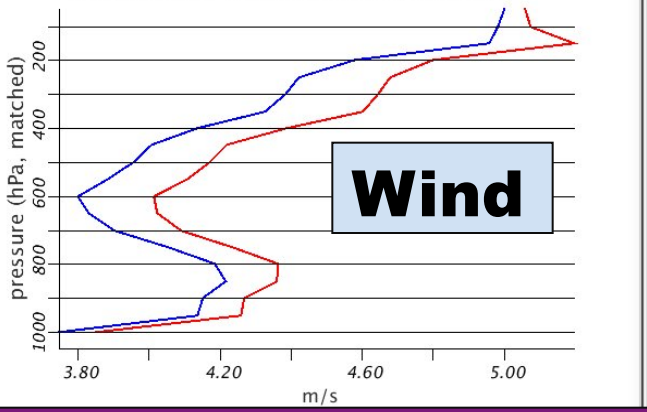
Contribution to community efforts (e.g., WRF, GSI) is critical. Enables R2O but also O2R.

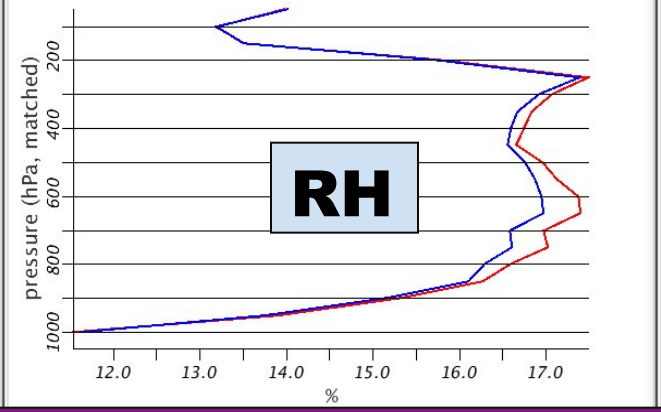
RAPv2 Hybrid Data Assimilation

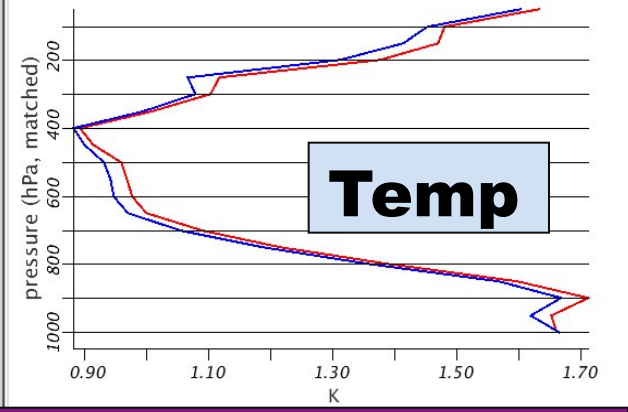
RMSE Vertical Profiles -- 22 Nov – 22 Dec 2012

RAPv2 Hybrid RAPv1 No Hybrid (3D-VAR)

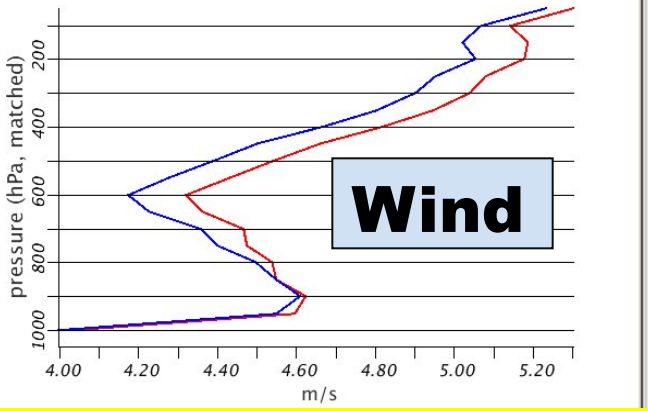
03-hr Forecast

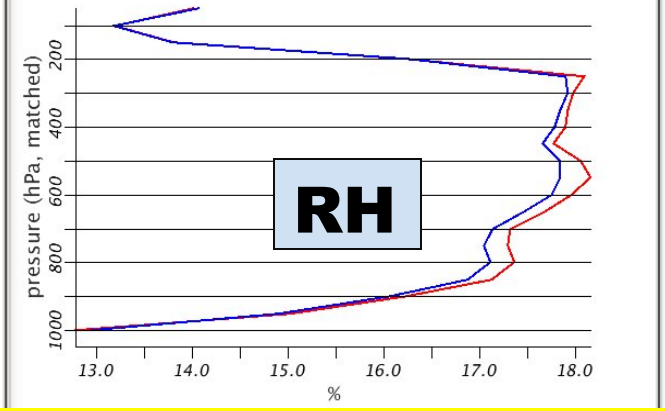


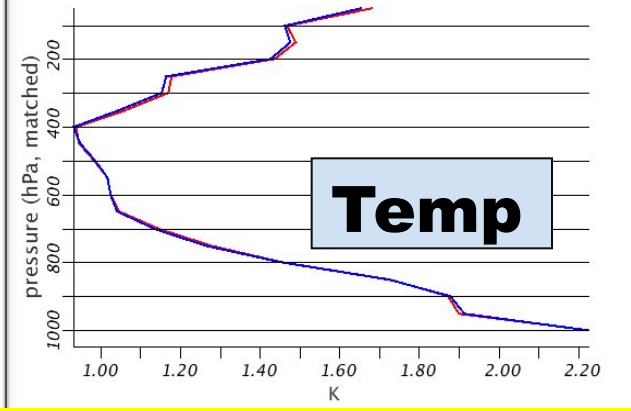




12-hr Forecast







Improved upper-air environment

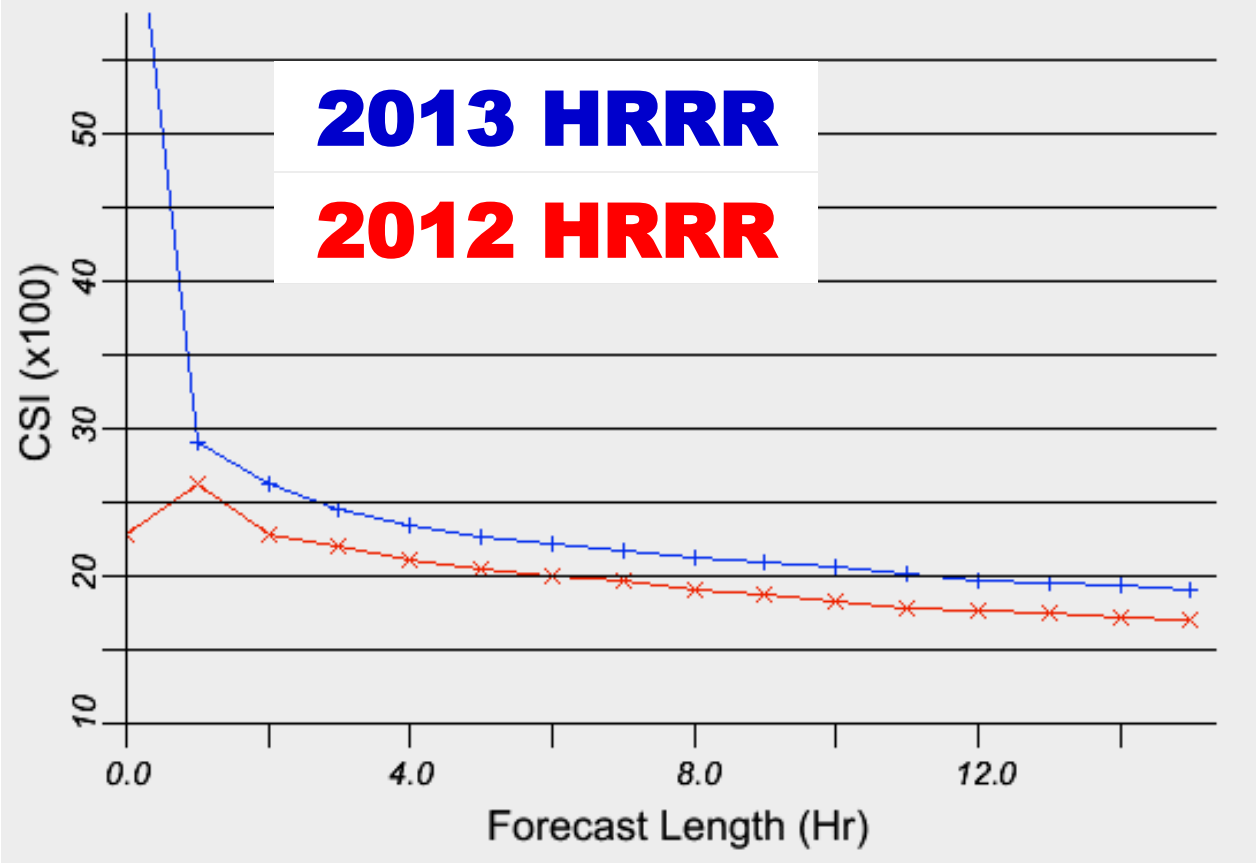
2013 HRRR improvements over 2012 HRRR

CSI vs. lead-time

25 dBZ reflectivity
40-km verif
Eastern US

Real-time
1 June – 31 Aug respective years

NOT event matched, but long-term and season match



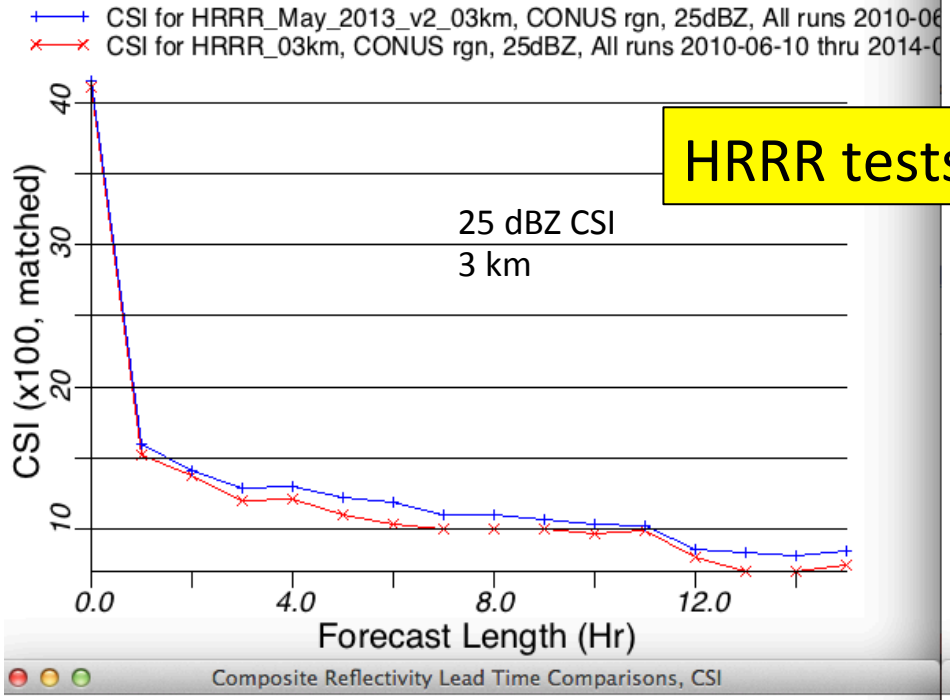
Improvements from **RAP DA (moisture pseudo-obs, soil-adjust, hybrid)** and from **HRRR 3-km radar DA**

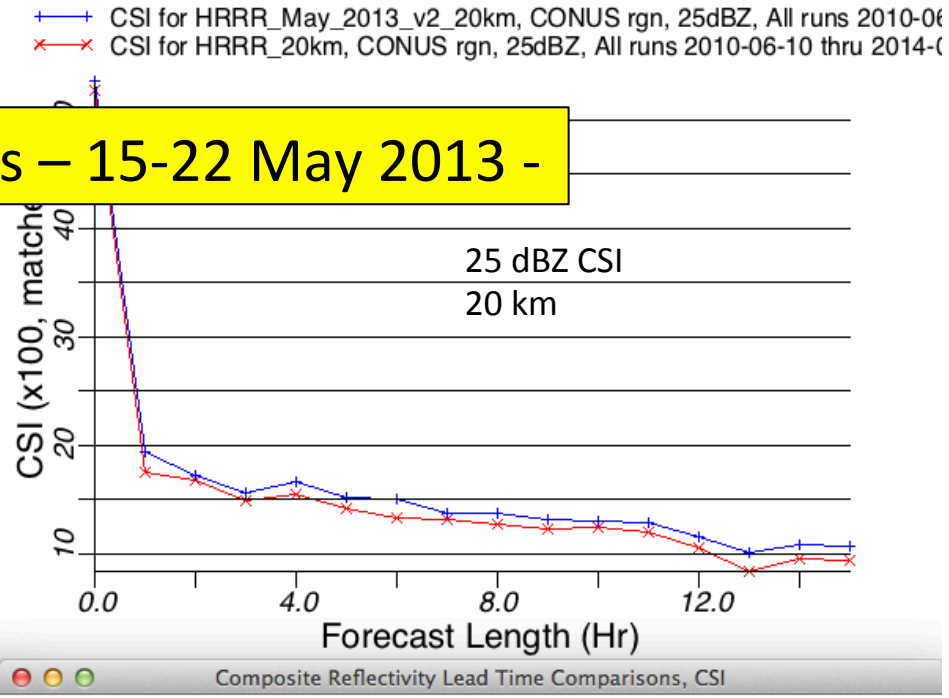
Candidate RAPv3/HRRRv2 Changes

	Model	Data Assimilation
RAP-ESRL (13 km)	WRFv3.5.1+ incl. physics changes Physics changes: Grell-Freitas convective scheme MYNN PBL scheme - Olson version RUC LSM update Thompson microphysics – v3.5.1 RRTMG radiation scheme Shallow cumulus parm w/ rad feed MODIS veg fraction/leaf area index	Merge with GSI trunk Increase ensemble weight in hybrid DA 8m→2m bkg for sfc Td assim Radiance bias correction New sat assimilation (NOAA-19, METOP-B, GOES)
HRRR (3 km)	WRFv3.5.1+ incl. physics changes Physics changes: MYNN PBL scheme - Olson version RUC LSM update Thompson microphysics – v3.5.1 RRTMG radiation scheme Numerics changes: 6th order diffusion in flat terrain smooth terrain @lat BC	3-km hybrid ens/var assimilation (was var-only in 2013) 8m→2m bkg for sfc Td assim Radar LH – 4x less intense than 2013 (2x less intense than RAP but more local)

Changes with high/medium importance for *overall* forecast skill

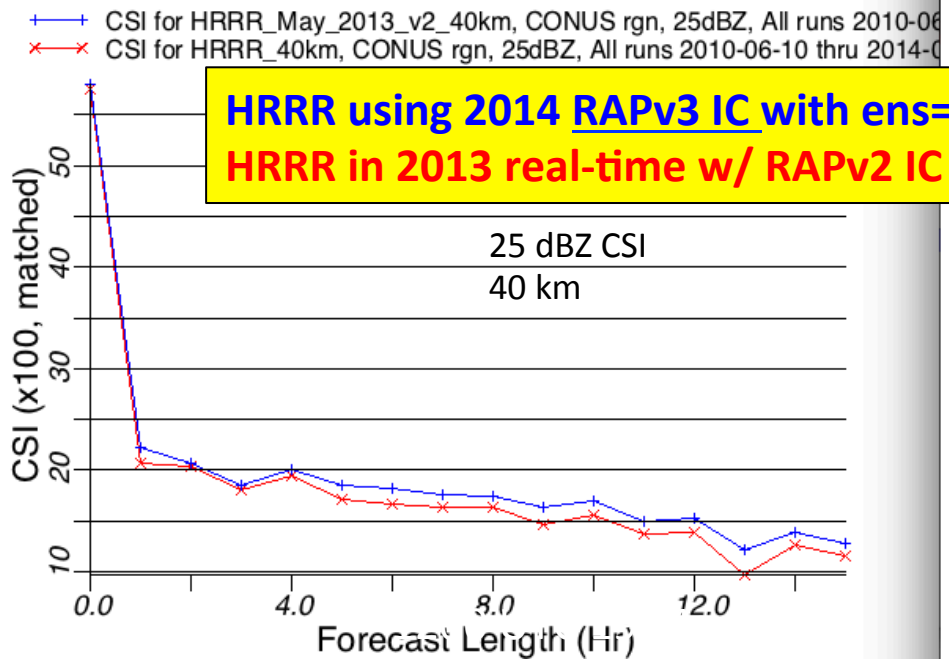
HRRR tests – 15-22 May 2013 -

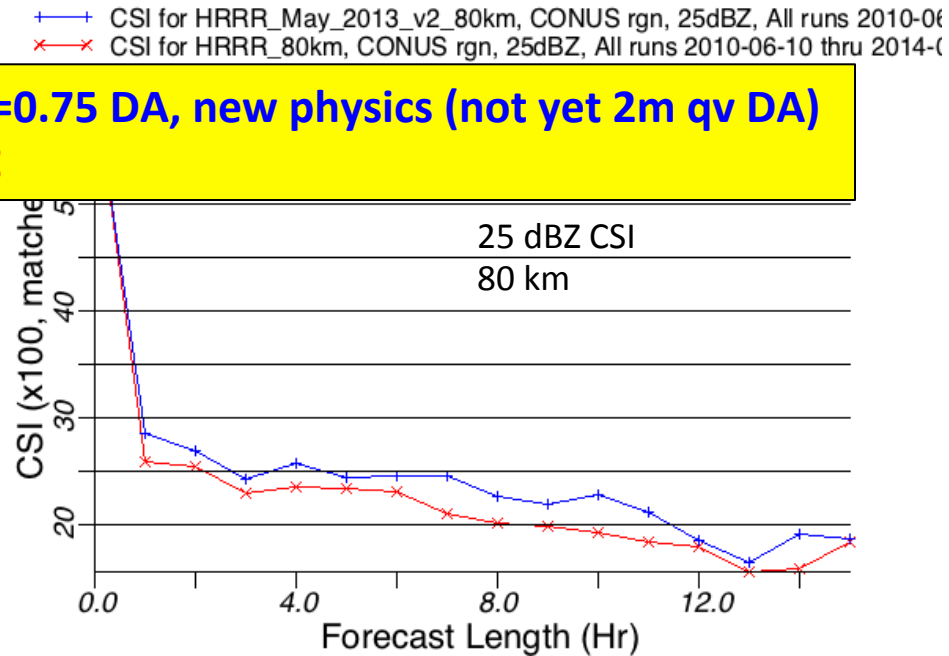




HRRR using 2014 RAPv3 IC with ens=0.75 DA, new physics (not yet 2m qv DA)

HRRR in 2013 real-time w/ RAPv2 IC





RAP/HRRR Implementation Map

ESRL – experimental version	NWS-NCEP - operational
• RAPv1 – used in 2011 – Initialized 2011 HRRR – effective but too many storms	• Implemented 1 May 2012
• **RAPv2 – used in 2012-2013** – **Initialized 2012-2013 HRRR** – **Better surface DA, hybrid DA radar**	• **RAPv2 - implemented scheduled on 25 Feb 2014** running in NCEP/NCO testing now
• **HRRR – 2012** – **Major improvement over 2011 (storm bias, coverage/accuracy)**	
• **HRRR – 2013** – **3km/15min radar assimilation** – **Initialized from RAPv2-2013** – **Available 45 min earlier, much more accurate 0-15h storm forecasts, more reliable 2-computer**	• **HRRR – Implementation scheduled for Aug 2014** HRRR testing on WCOSS with real-time end-to-end runs underway (Curtis, Ming heroics)

RAP/HRRR Implementation Map

ESRL – experimental version	NWS-NCEP - operational
• RAPv3 – to be used in 2014 – Will initialize 2014 ESRL-HRRR(v2) – Improved PBL, convection, sfc assim	→ • Implement early 2015
• RAPv4 – to be used in 2015 – Will initialize 2015 ESRL-HRRR(v3) – Target: hourly RAP ensemble for ensemble data assimilation	→ • Implement 2016
• **HRRRv2 – 2014** – **Improved radar assimilation, surface assimilation, PBL/cloud physics**	
• **HRRRv3 – 2015** – **To be initialized from RAP ensemble data assimilation + improved 3km physics (incl. aerosol-aware microphysics from NCAR/Thompson)**	→ • Implement 2015 → • Implement 2016

NOTE: ~42h HRRR forecast run 1-2x daily to start by May 2014 for energy and severe wx forecasts – on DOE computer. (

North American Rapid Refresh Ensemble (NARRE) ~2017@NCEP

- NMM, ARW cores
- Hourly updating with GSI-hybrid EnKF
- Initially 6 members, 3 each core, physics diversity (stochastic only or with RAP/NAM/ NCAR suites)
- Hourly forecasts to 24-h
- NMMB (+ARW?) members to 84-h 4x/day

NARRE/HRRRE Roadmap - Highlights – 2014-19

(for FAA Model Development & Enhancement Product Development Team)

2014 Implement HRRR (v1) at NCEP (convection, icing, terminal).

- Develop RAPv3 and HRRRv2 toward 2015 implementations at NCEP.
- Extension of HCPF and NARRE/TL into improved aviation probabilistic fields
- Start on 3km-ensemble-DA on small domain retro test

2015 Implement RAPv3 and HRRRv2 at NCEP.

- Implement regional ensemble data assimilation into parallel experimental RAP at ESRL into test version as part of continued NARRE development. Development of RAP and HRRR continues.

2016 Implement NAMRR at NCEP, using same single regional ensemble assimilation.

- Implement regional ensemble assimilation to initialize RAP/ NAMRR.

2018 Implementation for 6-member NARRE with ARW and NMMB members at NCEP for improved aviation probabilistic forecasts.

2019 Implementation of multi-member HRRRE with ARW and NMMB 3km-supercell-capable members at NCEP

Plan - Joint DTC/GSD Preliminary NARRE (Pre-NARRE) ensemble - as of Feb 2014

- Develop initial (*preliminary*) North American Rapid Refresh Ensemble (NARRE) configuration initially for retrospective experiments, later for intermittent real-time testing. – (Pre-NARRE)
  - ARW and NMMB dynamic cores
  - Initialization – ultimately, hourly - "Rapid" in NARRE
  - Forecast duration – depends on resources
    - For 2014 Pre-NARRE, run out to 24h every 3h. Also add out to 72h every 6h or 12h to replace current ExREF if we can reach agreement with previous ExREF users.
      - Dependencies: computer resources (#1), discussions with EMC on Pre-NARRE design, moving WPC and NWS-WR current ExREF users over to Pre-NARRE.
  - ~12km horizontal resolution
  - Both cores use same geographic domain, initially approximately that of the Rapid Refresh or perhaps slightly larger
  - Use RAP and NAM initial conditions for respective models
  - Develop capability for using alternative IC (NAM IC for RAP-ARW and RAP IC for NMMB), including hydrometeor fields and land-surface fields.
  - In collaboration with GSD/AMB colleagues, DTC staff and EMC staff, improve interoperability of needed physics parameterizations for ARW and NMMB.
  - Pre-NARRE may initially have 4 or more members, expand further in 2015 with stochastic physics or alternative physical parameterizations

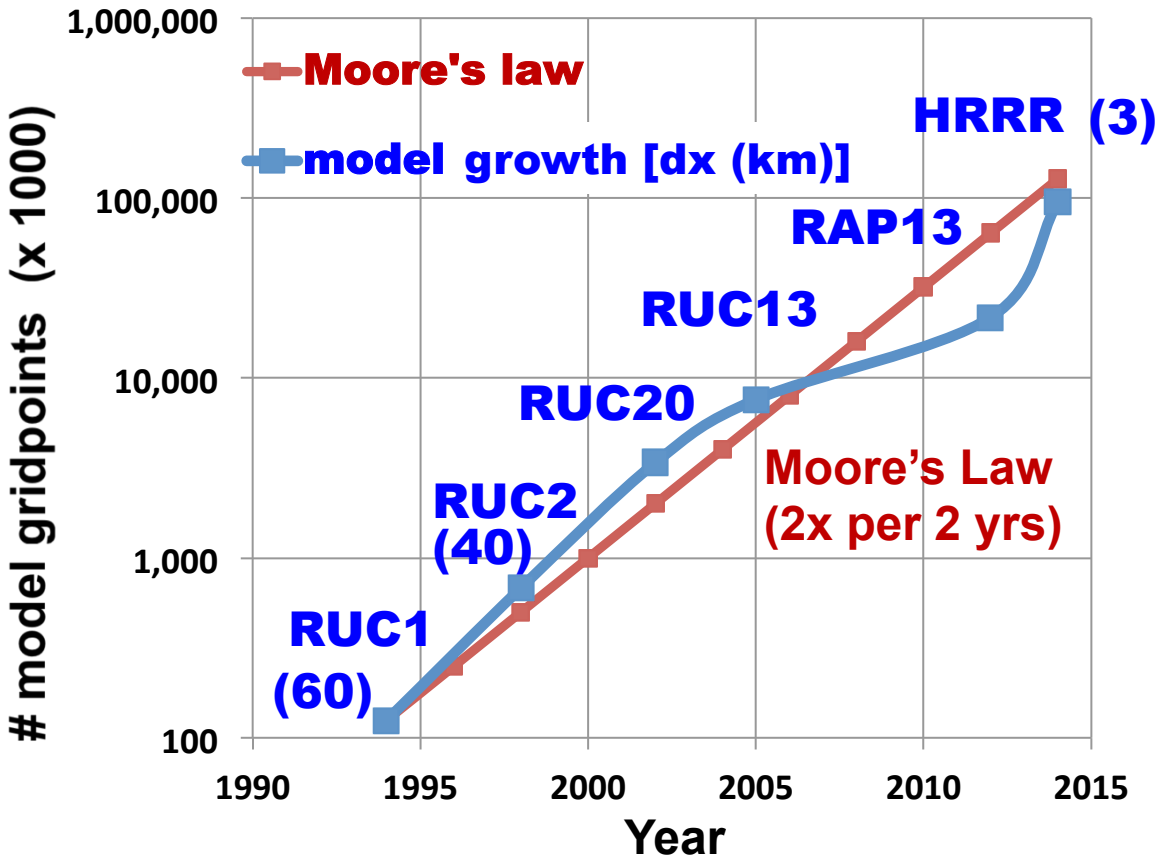
Plan - Joint DTC/GSD Preliminary NARRE (Pre-NARRE) ensemble – AMB, including Isidora Jankov

- Work primarily in collaboration with GSD/AMB model/assimilation development team.
  - Also collaborate with EMC Mesoscale Modeling Branch on NMMB usage.
  - Also work with DTC, as appropriate, on NMMB and Pre-NARRE testing
  - Work under regional ensemble goals for DTC and DTC Science Advisory Board, generally summarized: to be consistent with GSD/NCEP NARRE goals.
- Work with GSD/AMB and NCEP/EMC to develop ensemble products appropriate for NARRE.
- Work with GSD/AMB to verify experimental pre-NARRE tests.
- Work with GSD/AMB and DTC, as appropriate, to assist in development and evaluation of regional ensemble data assimilation efforts.

RUC / RAP / HRRR growth in number of model gridpoints* compared to Moore's law*

*NOTE: other aspects of the model system (# variables, etc.) also increased, making this a conservative estimate of model memory growth

*NOTE: Moore's law baselined to 1994 RUC1



RUC / RAP / HRRR model growth rate similar to Moore's Law

Directions for MDE for 2015-2025 to improve AHP forecasting & NAS efficiency

- Further improvement in data assimilation
  - Ensemble-based DA, later toward 4d-ens-var
    - Improve cloud/hydrometeor assimilation use of radar, PBL, satellite observations
- Probabilistic AHP fcsts thru hourly updated ensembles
  - **NARRE, HRRRE, improved global ensemble**
- Update frequency
  - Needs to go to every 30 min by 2020, then to 15-min in early 2020s and every 5-min by late 2020s
  - Use full NWP with high-frequency radar and satellite data
  - Coordination with NOAA Warn-On-Forecast plan (improved 1-2h forecasts updated on 5-min basis with storm-scale ensemble data assimilation)

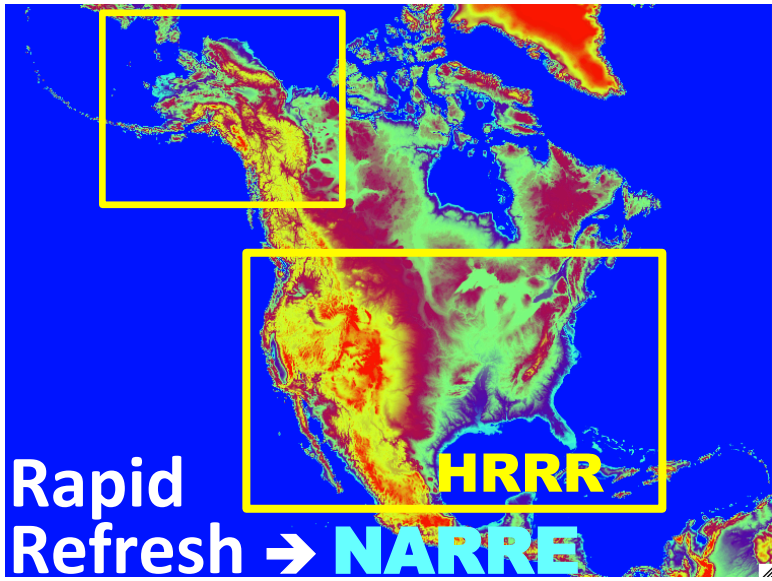
Evolution of hourly updated NOAA modeling

Feb 2014 Rapid Refresh v2 – NCEP oper

- PBL/soil/radar assimilation enhancements
  - ➔ **Improved surface forecasts, convective environment fields**
- Hybrid ensemble-variational GSI assimilation
- Model – improved cloud / PBL / LSM, numerics improvements, updated WRF

Aug 2014 – HRRR (3km) - planned NCEP oper with 3km/15min radar refl. assimilation

2015 – RAPv3 / HRRRv2



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- **Initially 6 members, 3 each core, physics diversity (stochastic only or with RAP/ NAM/NCAR suites)**
- **Hourly forecasts to 24-h**
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NARRE / HRRRE at NCEP

2017 – Ensemble Rapid Refresh/NAM – NARRE (w/ hybrid 4d-ens/var DA)

2019? – Ensemble HRRR – HRRRE – (ultimately with hourly ~3km ensemble DA)